Hybrid LES-RANS of flight effects on installed jet noise including fuselage

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Introduction

Reduction of jet noise through use of higher bypass ratios has significantly reduced isolated jet noise and installation effects generally, have become of higher relative importance. Engine airframe coupling is now if crucial importance and will remain so for future architectures. The effects of jet stream proximity to lifting surfaces has hence received growing attention. Numerical simulation can offer detailed data anywhere in the flowfield within ever shortening design cycles. It is of great interest to industry to begin replacing measurements with simulation for certification.

For a 3D wing and ultra-high bypass ratio (bypass ratio=15) nozzle with flight stream, Tyacke et al. [1] show upto 20dB increase (dependent on flap deflection) in mid-low frequencies over an isolated nozzle. For the same conditions, Wang et al. [2] show serrated nozzles weaken jet-wing interaction and can reduce noise by 5dB at the peak frequency. Unsteady surface pressures, calculated turbulence lengthscales and 2nd and 4th order space-time correlations indicate generally that reduced turbulence scale and intensity are responsible for lowered noise [2,3]. Vogel et al. [4] also study a coaxial jet (bypass ratio=5) with pylon and a single stream jet near ($1<h/D<3$) a flat plate. Source localisation is performed using beamforming identifying sources in the wake of the pylon, at the nozzle lip and plug. An increase in low frequency noise was observed for the installed cases.

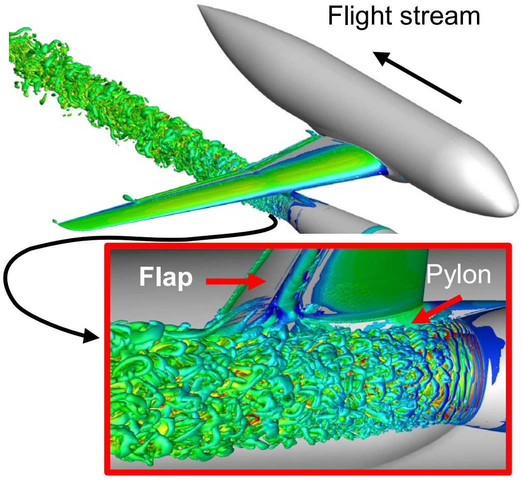


Figure 1 Geometry and instantaneous Q-criterion.

In order to extend and further test the authors' previous methodology, we contrast two flight stream velocities (F1 and F2) for an installed jet nozzle (bypass ratio=10.5) with a wing with deployed flap, connected to a fuselage with pylon. This is shown in Fig. 1. The latter two geometric components are in addition to previous studies. To the authors' knowledge, the presence of an entire fuselage has not been modelled using hybrid LES-RANS before. LES-RANS flow and acoustics data is validated against PIV and anechoic wind tunnel measurements.

Hybrid structured-unstructured mesh and Ffowcs Williams-Hawkings surface generation

The JERONIMO project considered installed round and serrated UHBR jet nozzles in close proximity to a wing-flap geometry. For this the authors used hybrid structured-unstructured meshes to maintain flow quality in the jet plume whilst providing greater geometrical flexibility. This was made possible by use of a Kinetic Energy Preserving (KEP) based spatial discretisation that provided more consistent dissipative qualities across various cell-types. Here the method is extended to include a pylon and fuselage and azimuthally varying mesh resolution is tested to reduce computational cost downstream where turbulence scales are large and noise sources weaken.

Ffowcs Williams-Hawkings surface generation and data processing

The same FWH surface generation method is used as per the JERONIMO project proving its generality. The surface used is shown in Fig. 2. In addition to acoustics data, 3D unsteady data sets were recorded for the full domain in order to build space-time correlations for sound source analysis. A parallel HDF5 I/O capability was built for this purpose allowing highly efficient data handling for pre and post processing.

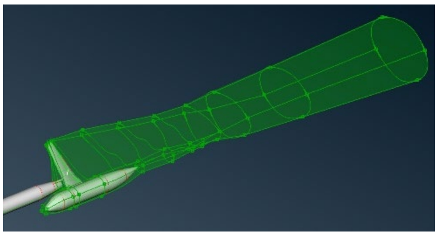


Figure 2 FWH surface.

Flow and acoustics validation

Figure 3 shows profiles of axial-velocity for two flight stream velocities (U(F1) < U(F2)) for the take-off engine condition. Excellent agreement is found between LES-RANS (L-R) and PIV (Exp.) data for flight stream 1 where measurements were available. Figure 4 again shows agreement between numerical and measured data. As expected, reduced shear due to velocity ratio variation reduces peak turbulence levels. Peak location is also modified by the elongation of the jet plume by increased external flight stream velocity.

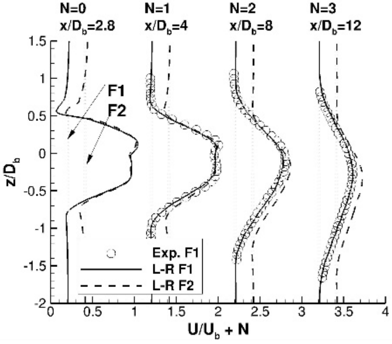


Figure 1 Axial velocity profiles downstream of the nozzle.

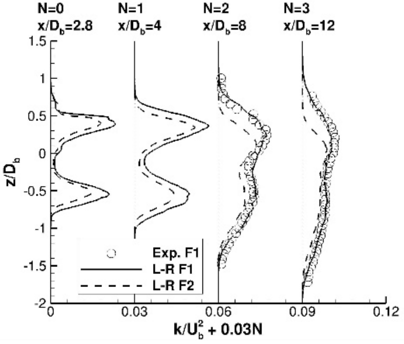
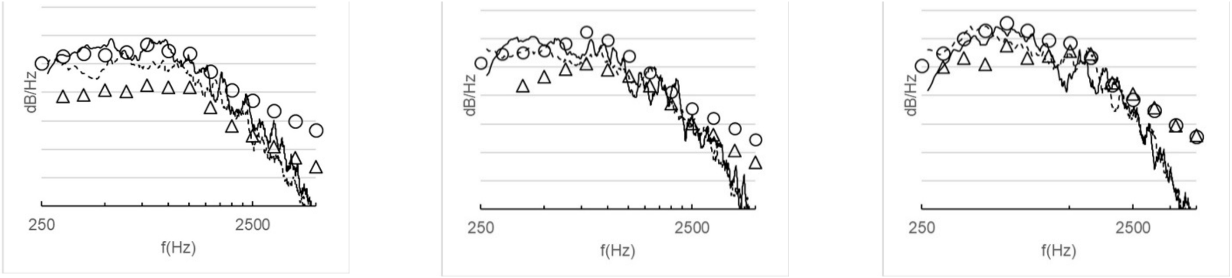


Figure 2 Turbulence Kinetic Energy profiles downstream of the nozzle.



(a) 60 deg. (b) 90 deg. (c) 120 deg.

Figure 5 SPL spectra for different polar angles at flyover. Circles (F1) and triangles (F2) represent measurements. Solid (F1) and dashed (F2) lines represent LES-RANS. 5dB increments indicated.

The overall spectral shape is represented as per the measurements for F1 and F2 cases. The noise reduction due to increased flight stream velocity appears underestimated in the low frequencies. The reason for this is under further investigation given the significant decreases in TKE. At a polar angle of 60 degrees the low frequency noise is reduced to a greater extend than at 120 degrees. This may be explained by the reduction in turbulence near the flap trailing edge and reduction in mixing noise in the shear layers. The LES-RANS becomes under-resolved at frequencies higher than ~2500 Hz. At mid-frequencies, numerical and measured data are similar. Given the great deal of geometric and flow complexity, the predictive accuracy over a range of frequencies is notable.

References

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